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Fiber Drawn 2D Polymeric Photonic Crystal THz Filters

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Abstract: In this paper, we report on different polymeric 2D photonic crystal filters for THz frequencies which are fabricated by a standard fiber drawing technique. The bandstop filters were simulated and designed by the generalized multipole technique (GMT). The frequency and angle dependent transmission characteristics of the photonic crystal structures were characterized in a pulsed terahertz (THz) time domain spectrometer.

OCIS codes: (000.0000) General; (000.0000) General

1. Introduction

Even though THz science and technology have been growing over the last 20 years, the lack of available passive components is one of the reasons that industrial and commercial THz systems are just emerging [1]. Especially frequency selective components like Bragg gratings and filters are necessary to realize cheap and versatile sensing systems for industrial applications. Typical filter concepts for the terahertz regime are close adaptations from either the optical or millimeter domain. The concepts from the RF field comprise metallic mesh designs and frequency selective surfaces, e.g. based on metamaterials [2]. Photonic crystal structures are the most promising optical concept for realizing THz filters. They have been fabricated by photo lithography [3], deep reactive-ion etching [4], laser based micromachining [5] or micro assembly [6].

In this paper we report on a fast and cheap method to fabricate scalable polymer based THz filters with mass production capability. First fabrication runs were performed in polycarbonate (PC) and in the Cyclic Olefin Copolymer (COC) TOPAS, which has low loss in the THz frequency regime [7]. The structures were simulated by a customized algorithm based on the Generalized Multipole Technique (GMT) [8]. A tube like preform (6 cm outer diameter (OD), 4.3 cm inner diameter (ID)) was loaded with several hundreds of small tubes (1 mm OD, 0.745 mm ID) and then drawn down in a standard fiber drawing tower (cf. Fig.1b). This provides a sufficient numbers of periods and a pronounced dip in transmission.

2. Results

The simulation result for a triangular lattice structure in polycarbonate (cf. Fig. 1a) with air hole diameter D_h = 260 µm and a pitch of D = 370 µm performed with the GMT is shown in Figure 1c. The simulations take the frequency dependent dielectric loss of the material into account. The solid and dotted line show the band diagrams for the first two horizontally polarized modes. For a fixed hole-diameter-to-pitch ratio of 0.745, the center stop band frequency versus the spacing of the holes is calculated.

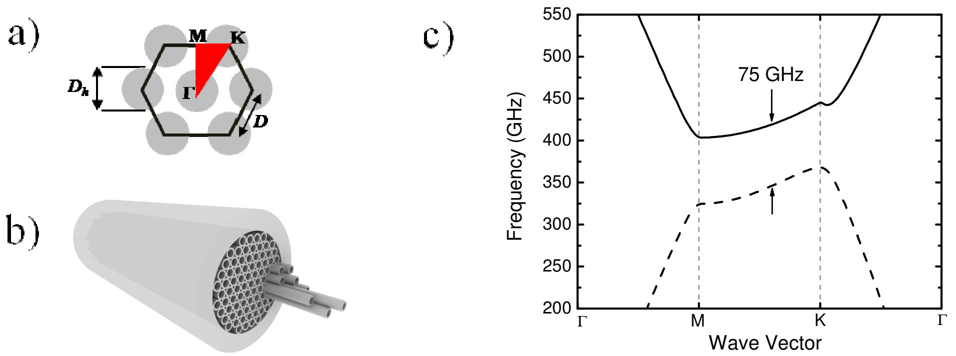

Fig. 1. a) The triangular photonic crystal structure b) Schematic of a stacked preform c) Band gap diagram for a polycarbonate 2D photonic crystal with 370 µm hole spacing (hole diameter-to-pitch (D_h/D) of 0.745).

To access feature sizes of 200 µm and below a standard fiber drawing technique is used. Stacked tubes in a cylindrical preform are utilized to achieve the desired number of periods within the filter and to guarantee the optimal hole-diameter-to-pitch ratio. The pull ratio determines the final filter dimensions and therefore the resulting frequency characteristics. Thus, it is now possible to access a very broad range of frequencies, typically from three digit GHz frequencies up to several THz. The interstitial holes were closed by applying low pressure.

A standard THz time domain spectrometer with a bandwidth of more than 4 THz was used to analyze the polymer photonic crystal filters of approximately 1 cm length. The transmission spectrum of a polycarbonate filter with a hole spacing of 375 µm and a TOPAS filter with a hole spacing of 55 µm are shown in Figure 2a and b.

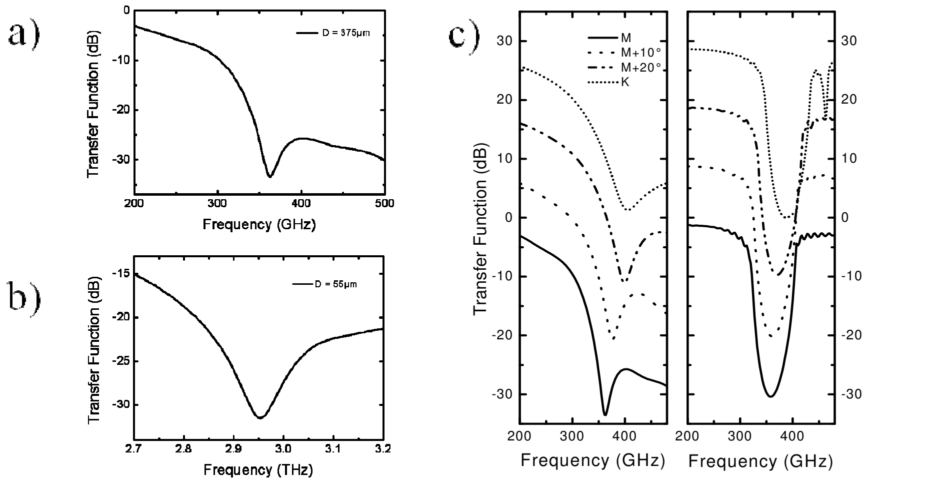

Fig. 2. Measured transfer function for a polycarbonate filter with (a) and a TOPAS filter with D = 55 µm (b). On the right hand side are measured and GMT simulated relative transmittance (c) at varying incident angles for a polycarbonate THz filter with a hole spacing of D = 375 µm. For clarity, the graphs are offset by 10 dB/10° with respect to the 0°-curve.

Placing the polycarbonate filter on a rotatable mount the angle dependent frequency characteristics have been investigated. A series of measurements from 0° (M-point) to 30° (K-point) in 10° steps confirm the predictions of the GMT simulations. In Figure 2c, the measured data is shown next to the simulation results (cf. right side of Figure 2c). The expected blue shift of the resonance frequency was observed for increasing angles of incidence

3. Conclusion

We present a first proof-of-concept experimental demonstration of polymeric 2D photonic crystal THz filters, fabricated by a standard fiber drawing technique. Angle and frequency dependent transmission measurements were performed in a pulsed THz time domain spectrometer confirming that the resonance frequency of the filter can be shifted by rotating the filter with respect to the incoming THz wave. The fabrication method relies on standard fiber drawing techniques and can therefore easily be used for mass production. Furthermore, adjusting the scaling factor enables the free scalability of the targeted resonance frequency using a single preform design.

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